

Climacograptus pygmaeus and Associated
Graptolites and Enigmatica
of the Ripley, Ohio, Maysville, Kentucky
and Sherburne, Kentucky Areas

Presented in Partial Fulfillment of the Requirements
for the Degree, Bachelor of Science

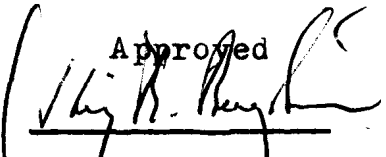
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INTRODUCTION

Graptolites occur very sparingly in the Upper Ordovician strata of the Cincinnati region. Among the graptolites present, by far the most common is Climacograptus typicalis Hall which is a widespread and locally abundant fossil in the Kope Formation. The biostratigraphically important graptolite C. pygmaeus Ruedemann is apparently an offshoot of the C. typicalis lineage. Collections of C. pygmaeus from the Cincinnati area have been discussed recently (Riva 1974, Mitchell and Bergstrom 1977) but the stratigraphic range in the Cincinnati has never been adequately defined. The primary purpose of this study was to investigate the occurrence of C. pygmaeus in the Cincinnati area and to determine the stratigraphic position and range of this species. A second objective was to study the morphological differences between C. pygmaeus and C. typicalis on the basis of well-preserved isolated specimens. During the course of this investigation, specimens of Orthograptus sp. and the enigmatic organic-walled microfossil Chitinodendron Eisenack were also isolated and studied.

The collection studied herein are from five localities (Fig. 1).

Locality A. Roadcut along US Rt. 68 in the SE 1/4 of the Russelville, Ohio 7½' Quadrangle. The exposure is on the east side of the road just north of North Pole Rd. at the 10 mile marker. An interval approximately 30 meters below the top of the Kope Formation is exposed at this site.

A)

Figure 1

B)

Localities

A) Regional map of the area of study.
Scale = 1:250 000

B) A portion of the Russellville, Ohio 7½' Quadrangle showing Locality A.

C) A portion of the Maysville West, Ohio-Kentucky 7½' Quadrangle showing Localities B, C and D.

D) A portion of the Sherburne, Kentucky 7½' Quadrangle showing Locality E.

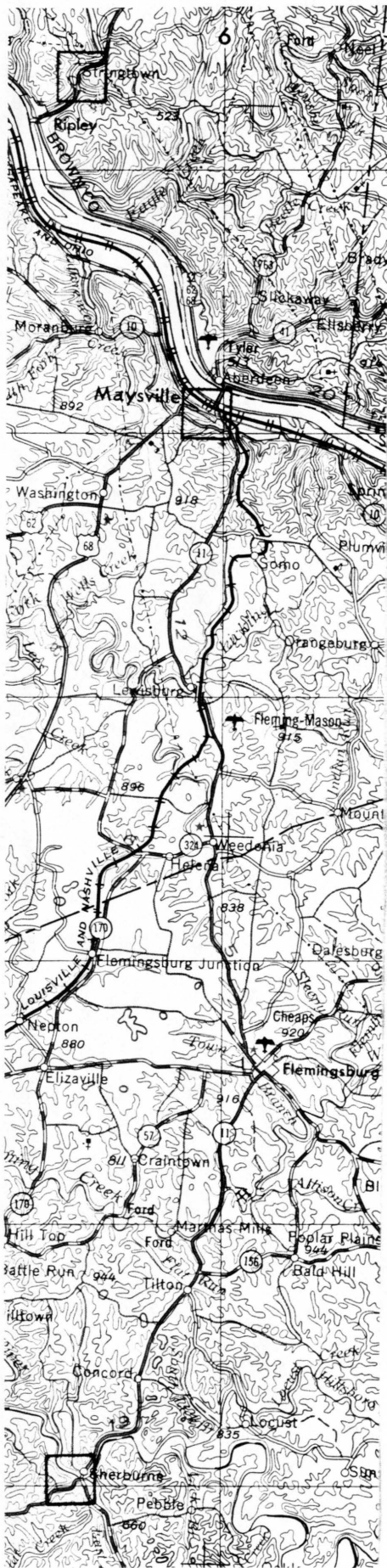
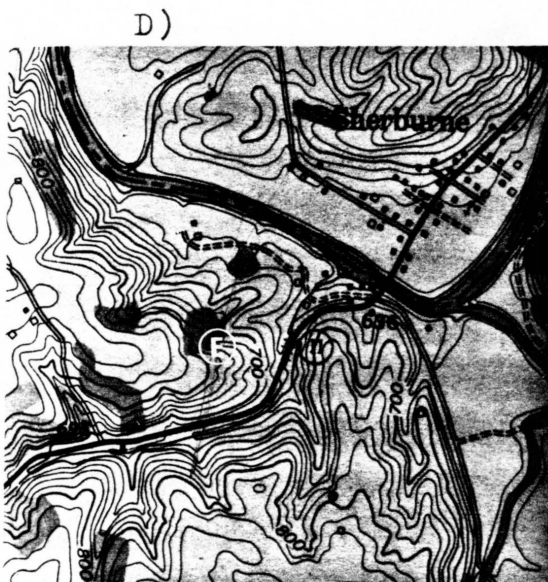




Figure 2

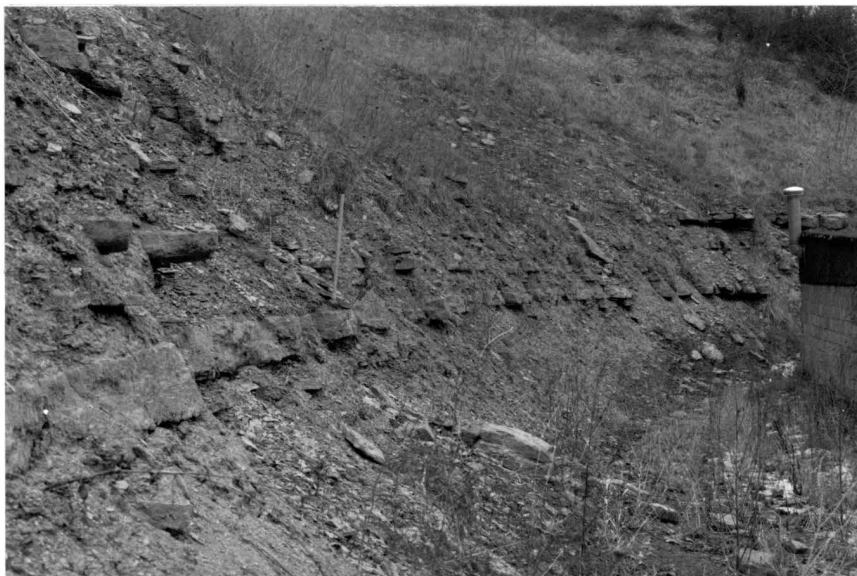
Locality A. West side of US 68 north of Ripley, Ohio. Sample 79E3-2 containing abundant Climacograptus typicalis was collected 4.5 m above road level.

Figure 3

Locality B. Cut behind Pepsi-Cola warehouse at Maysville, Kentucky. Sample 80E5-f containing the transitional population was collected from debris at the base of the cut. Arrow indicates level at which flattened specimens of C. pygmaeus were found in shales. Length of sledge hammer = 80 cm.



Figure 4



Locality D. Cut at the west side of the Styleline Furniture Company Store at Maysville. Sample 79E2-f containing abundant Climacograptus pygmaeus was collected from debris at the base of the cut. Sample 79E2-f probably represents a thin limestone lens from below Bed 80E1-3 (sledge hammer).

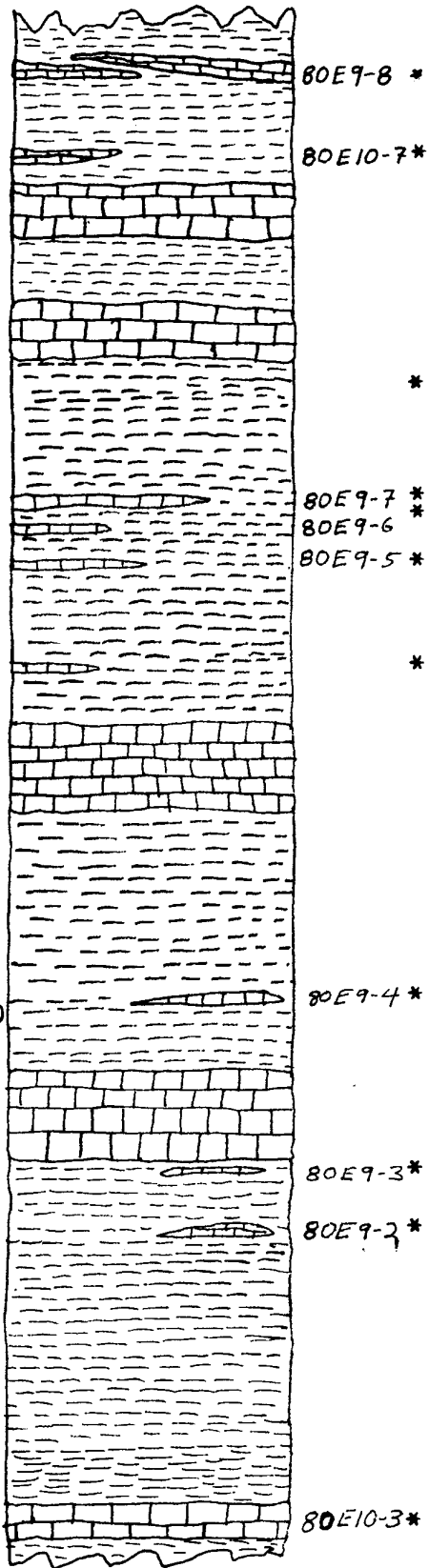
Figure 5



Locality E. Roadcut along Ky. Rt. 11 near Sherburne, Kentucky. Upper arrow indicates approximate level of the Kope-Fairview contact. Lower arrow indicates level of Sample 80E10-3 containing abundant C. pygmaeus. Measured sections from Localities D and E are presented in Figure 6.

Figure 6
Measured sections

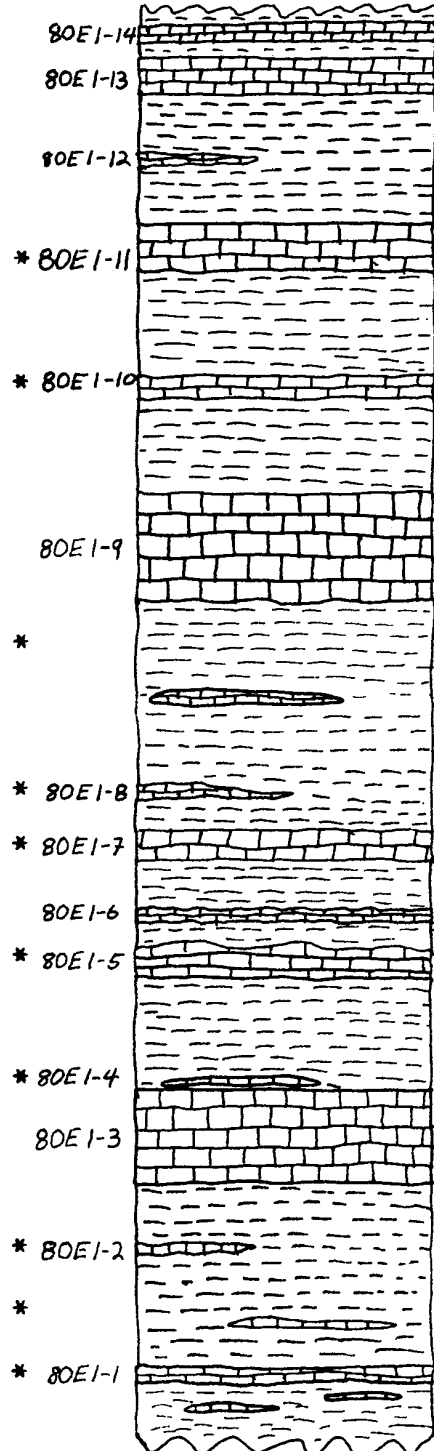
LOCALITY E



Vertical
Scale 1:40

Bar=
1.0 m

LOCALITY D



* indicates graptolite bearing
horizon

Locality B. Cut in the hillside behind the Pepsi-Cola warehouse at Maysville, Kentucky in the SE 1/4 of the Maysville West 7½' Quadrangle. The uppermost beds exposed at this site are about 25 m below the top of the Kope Formation.

Locality C. Hillside exposure beside the parking lot of the Heck's Department Store at Maysville. Locality C is across US 68 from Locality B. Localities B and C are separated by about 220 meters.

Locality D. Cut at the west side of the Styleline Furniture Company Store at Maysville. The base of this cut is about 10 m below the top of the Kope Formation. Locality D is about 390 meters west of Locality B.

Locality E. Roadcut along Ky. Rt. 11 near the village of Sherburne, just south of the Licking River in Bath County, Kentucky. The uppermost beds of the Kope Formation and the lowermost beds of the Fairview Formation are exposed at this site. Locality E is 40 km south of Locality B. Measured sections from Localities D and E are presented in Figure 6.

OCCURRENCE OF GRAPTOLITES

Graptolites occur in several intervals in the exposures studied and in a variety of lithologies. Flattened rhabdosomes are found in great abundance on certain bedding planes of the shales and calcareous siltstones. Such occurrences often proved useful for the location of graptolitiferous limestones since they are readily located in the field. Three-dimensionally

preserved graptolite rhabdosomes occur in certain of the coarser limestones. Whenever possible, attempts were made to get field collections of limestones which grade into graptolitiferous calcareous siltstones. Such samples usually produced beautifully preserved three-dimensional material. In the limestones, the rhabdosomes are randomly oriented. On the bedding surfaces of the shales and siltstones some preferential orientation was observed. This was caused by currents during deposition.

In four instances populations of more than fifty mature (five or more thecae per stipe) rhabdosomes of the genus Climacograptus were obtained from the limestones by etching with acetic or hydrochloric acids. In each case where mature specimens were present, a large assortment of growth stages were also isolated. In most cases, the number of growth stages was far greater than the number of mature specimens.

When residues containing isolated graptolites were searched under water, a number of specimens of the enigmatic microfossil Chitinodendron were recovered. All the specimens of this fossil collected were from limestones, but the tiny size of specimens of this taxon precluded easy finding of flattened specimens on bedding planes. All the specimens of Chitinodendron collected during this study were found in association with graptolites, but this may not necessarily mean that a life relationship existed between Chitinodendron and graptolites. Specimens of Chitinodendron are also present in a sample dissolved in a search

for chitinozoans during a separate study by Knabe (1980). No graptolites were isolated from his sample, which is from the Kope Formation.

STRATIGRAPHIC ORIGIN OF SAMPLES AND BIOSTRATIGRAPHY

All the collections studied were from rocks of the Kope Formation. The Kope Formation consists primarily of shale with beds of limestone which are in most cases less than 25 cm thick. The limestones are commonly very fossiliferous and all fall within classes described by Weiss and Norman (1960). The upper portion of the Kope Formation at Maysville, Ky. has been correlated with the lower Fairview Formation of Cincinnati by Carpenter and Ory (1961). This implies a Maysvillian age for these strata. This upper part of the Kope Formation at Maysville is the interval from which the specimens referable to Climacograptus pygmaeus were collected.

For the purpose of this investigation, graptolites were collected from several horizons. Whenever possible, specimens were collected from rocks in situ. This was not always possible and the largest collection of Climacograptus pygmaeus as well as a population of a form transitional between C. typicalis and C. pygmaeus were both collected from the debris at the base of the respective outcrops. The largest populations of graptolites and other fossils were obtained from the following horizons:

- 1) Sample 80E3-2 -- A collection of 50 specimens of C. typicalis

collected for comparative purposes, from a horizon approximately 30 m below the top of the Kope Formation at Locality A.

2) Sample 79E2-f -- A collection of more than 100 specimens of C. pygmaeus from the float at the base of the outcrop at Locality D. Carpenter and Ory (1961) determined the top of the Kope Formation at this site to be at an elevation of 211.3 m (682 feet). The base of this outcrop is at about 201 m and the largest number of graptolites in situ were found in the lower 1 m (below Bed 80E1-3, see measured sections). It is therefore likely that this population represents a horizon about 10 m below the top of the Kope Formation.

3) Sample 79E3-f -- This sample, which yielded my largest collection of the enigmatic microfossil Chitinodendron, was also found in the float with the previous sample.

4) Sample 80E5-f -- A collection of a form transitional between Climacograptus typicalis and C. pygmaeus was obtained from this sample from the float at Locality B. The top of this outcrop is at an elevation of 196 m. I have recovered flattened specimens from the upper 2.5 m of this outcrop, which resemble C. pygmaeus more than specimens of the transitional population from this sample. Sample 80E5-f therefore probably came from a horizon near the base of this 7 m outcrop, perhaps from an elevation of 189-192 m.

5) Sample 80E10-8 -- Most of the specimens of Orthograptus sp. came from this sample from Locality C. The elevation is probably

between 183 m and 186 m.

6) Sample 80E10-3 -- A collection of 55 mature rhabdosomes of C. pygmaeus was obtained from this sample from Locality E. The top of the Kope Formation at this locality has been mapped by Outerbridge (1970) at an elevation of 242 m. Sample 80E10-3 originates from a horizon at 231 m.

At Localities D and E limestones were sampled at random in an effort to determine the top of the local stratigraphic range of Climacograptus pygmaeus. At Locality D the highest occurrence of C. pygmaeus was in Sample 80E1-11 at an elevation of 204.5 m, about 7 m below the top of the Kope Formation. At Locality E the uppermost occurrence was in Sample 80E9-8 at an elevation of 235 m, again about 7 m below the top of the Kope Formation.

Climacograptus pygmaeus is an important index fossil. Its range defines the lower subzone of Zone 14 (the Orthograptus quadrimucronatus Zone) of the North American graptolite succession (Berry 1971, Mitchell and Bergström 1977). It is (Ruedemann 1947, Riva 1969, Fisher 1980) the characteristic guide fossil for the upper division of the Utica Shale in New York and equivalent strata on Anticosti Island. Berry (1971) states that the boundary between his graptolite Chronozones 13 and 14 falls either within the Eden or above it. If the base of Berry's Chronozone 14 in the Ohio Valley may be taken as the lowest appearance of C. pygmaeus, then the present study shows

level is in rocks correlative with the lower Maysvillian of the type Cincinnati in the Cincinnati area.

SYSTEMATIC PALEONTOLOGY

Class Graptolithina Bronn, 1846

Order Graptoloidea Lapworth, 1875

Family Diplograptidae Lapworth, 1873

Genus Climacograptus Hall, 1865

Climacograptus typicalis Hall

Climacograptus typicalis Hall, 1865, p. 57, Pl. A, figs. 1-9;

Ruedemann, 1908, p. 407-411, Text-figs. 354-362, Pl. 28, figs. 6-7; Ruedemann, 1947, p. 440-441, Pl. 75, figs. 27-38; Erdtmann and Moor, 1973, p. 1081-1093, Text-figs. 1-6, Pl. 1-2.

Description.---Specimens herein referred unconditionally to this taxon are members of a population obtained from Sample 80E3-2, Locality A, approximately 30 meters below the top of the Kope Formation. This species has been described in detail by Erdtmann and Moor (1973) and is a widespread and well-known species. Fifty isolated specimens of this population have an average width of 0.52 mm at the first thecal aperture (th_1^1) (see Table 1). They widen distally to an average 0.78 mm at the th_5^1 aperture. At the th_9^1 aperture, 8 specimens have an average width of 1.05 mm. Distal fragments up to 1.4 mm wide have been isolated from sample. Rhabdosomal widths at successive

thecal apertures have been plotted for this and other large populations of Climacograptus in Fig. 7. The distance from the base of the virgella to the $th5^1$ aperture averages 3.2 mm for 25 specimens. Considerable variation in this distance was noted for this population. Measurements varied from 2.8 mm to 3.7 mm with a standard deviation of 0.25 mm.

Cortical bandages, such as those reported by Crowther and Rickards (1977), were observed with the Scanning Electron Microscope on the exterior of one specimen from this population. (Pl. 3, fig. 7).

Discussion.---Size frequency distribution graphs (Figs. 8-11) of rhabdosomal widths at successive thecal apertures suggest that variations in these parameters are due to variations within a monospecific population and are not owing to the presence of a mixture of C. typicalis and C. pygmaeus in the populations studied. Erdtmann and Moor (1973) obtained means of 0.47 mm and 0.74 mm for rhabdosome widths at $th1^1$ and $th5^1$ respectively.

Climacograptus pygmaeus Ruedemann

Climacograptus pygmaeus Ruedemann, 1925, p. 63; Ruedemann, 1947, p. 435-436, Pl. 72, figs. 22-24, Fisher, 1980, Text-figs. 62, 64a-d.

Diplograptus edenensis Ruedemann, 1947, p. 416, Pl. 71, figs. 10-14.

Description.---Two large populations referred to this species

and one containing specimens transitional between C. typicalis and C. pygmaeus were studied in detail and are described below. In addition to these large populations, specimens from the Museum of Comparative Zoology at Harvard University and from the University of Kentucky were also studied and measured. These results are included also. The specimens from the University of Kentucky, Department of Geology, were previously identified as Diplograptus edenensis Ruedemann and apparently include the holotype of that species.

From Sample 79E2-f, 103 specimens complete to $th5^1$ were examined and measured. At $th1^1$, a mean width of 0.44 mm was obtained based on 99 specimens. The width at $th1^1$ varies between 0.39 mm and 0.52 mm with a standard deviation of 0.03 mm. These specimens widen distally to a mean of 0.62 mm at $th5^1$ based on 103 specimens. These measurements vary between 0.51 mm and 0.83 mm with a standard deviation of 0.06 mm. Seven specimens complete to $th9^1$ have a mean width of 0.74 mm. The widest rhabdosome encountered in this population was 0.93 mm wide at $th6^1$. Distal fragments from this sample did not exceed this value. The distance from the base of the virgella to the $th5^1$ aperture averages 2.8 mm, varying from 2.4 mm to 3.2 mm with a standard deviation of 0.17 mm.

Sample 80E10-3 yielded a population with the following measurements: Mean width at $th1^1$, (55 specimens), 0.44 mm; variation in width at $th1^1$, 0.39 mm - 0.51 mm; standard deviation of width at $th1^1$, 0.03 mm; mean width at $th5^1$, (55 specimens),

0.72 mm; variation in width at $th5^1$, 0.55 mm - 0.93 mm; standard deviation of width at $th5^1$, 0.08 mm; mean width at $th9^1$ (5 specimens), 0.08 mm; variation in width at $th9^1$, 0.80 mm - 0.88 mm. The widest specimen from this sample measures 0.93 mm at $th5^1$. No distal fragment exceeds this specimen in width. Twenty-five specimens from this population average 2.8 mm from the base of the virgella to the $th5^1$ aperture. These measurements vary between 2.5 mm and 3.2 mm with a standard deviation of 0.19 mm.

The transitional population was obtained from Sample 80E5-f. Fifty specimens were examined and measured with the following results: mean width at $th1^1$ (49 specimens), 0.46 mm; variation in width at $th1^1$, 0.40 mm - 0.52 mm; standard deviation of width at $th1^1$, 0.03 mm; mean width at $th5^1$ (50 specimens), 0.67 mm; variation in width at $th5^1$, 0.55 mm - 0.83 mm; standard deviation of width at $th5^1$, 0.07 mm; mean width at $th9^1$ (7 specimens), 0.98 mm. The widest distal fragment from this sample is 1.4 mm wide. The distance between the base of the virgella and the $th5^1$ aperture averages 3.3 mm for 25 specimens, varying between 3.1 mm and 3.6 mm with a standard deviation of 0.14 mm.

Sample 80E10-7 contains few undamaged rhabdosomes but five specimens complete to $th5^1$ were found. These are the stratigraphically highest mature rhabdosomes collected during this investigation. The specimens average 0.42 mm wide at $th1^1$ and 0.60 mm wide at $th5^1$.

Thirteen isolated specimens from the Museum of Comparative Zoology at Harvard University were measured with the following results: mean width at th1¹ (13 specimens), 0.55 mm; variation in width at th1¹, 0.49 mm - 0.60 mm; standard deviation of width at th1¹, 0.03 mm; mean width at th5¹ (11 specimens), 0.76 mm; variation in width at th5¹, 0.65 mm - 0.81 mm; standard deviation of width at th5¹, 0.06 mm. The widest of these specimens is 0.92 mm wide at th8¹.

Specimens from the University of Kentucky, Department of Geology were originally described by Ruedemann (1947) as Diplograptus edenensis. The specimens he described are preserved in three dimensions in limestones. Regretably, little of the periderm remains on these specimens. This fact may account for Ruedemann's incorrect identification of this material. I have dissolved a small portion of a slab on which are many of these small poorly-preserved specimens. This sample produced many very fragile specimens of Climacograptus pygmaeus, however, no other graptolite species is present. I therefore believe that D. edenensis and C. pygmaeus are synonymous. These specimens are remarkable in their length. Many have more than ten thecae per stipe and at least one has more than twenty. This very long specimen (Pl. 2, fig. 13) is damaged on the proximal end and no remnant of the sicula remains. It is 1.01 mm across at its widest point.

Discussion.---The specimens of Climacograptus pygmaeus from the study area resemble C. typicalis in every feature except size. Differences between the two species become

evident in large populations of rhabdosomes developed to th5 or th6, and the differences become obvious in mature specimens developed to th10 or more. The rate at which rhabdosomes of C. pygmaeus widen decreases significantly at the level of th5¹ or th6¹ (Fig. 12). In the populations of C. typicalis, the rhabdosomes continue to widen rapidly (more than 0.06 mm per theca) until about th10, at which level the rate of expansion decreases. Specimens of C. pygmaeus usually widen to no more than 0.9 mm whereas specimens of C. typicalis continue to expand until the rhabdosome is more than 1.0 mm wide. The transitional population is very similar to the basic C. typicalis population. The only significant difference is in the width of the proximal end. In this respect, the transition population more closely resembles the populations of C. pygmaeus. Logically, a smaller proximal would be a necessary first step in the evolution of narrower rhabdosomes. The proximal end development of this transitional population may illustrate this trend.

As is the case with the population of C. typicalis, size frequency distribution graphs of rhabdosome widths at successive thecal apertures (Figs. 8-11) indicate that no mixing of species occurs in these populations of Climacograptus.

Growth abnormalities.---Several specimens with various growth abnormalities were isolated during this investigation. Several types of growth abnormalities occurred in the specimens of Climacograptus studied:

- 1) Growth of a second supragenicular flange. This abnormality

was noted by Erdtmann and Moor (1973) in their specimens of C. typicalis and was observed during the present study in both C. typicalis and C. pygmaeus. Careful examination of this variation suggests that the zooid of the preceding theca produced the extra flange first and later produced the flange covering the thecal aperture. (Pl.3, fig.7).

2) Extra thecae budding from $th1^1$. Three specimens exhibit this highly unusual condition. One specimen from Sample 80E3-2 possesses an extra theca budding from $th1^1$ at the base of the virgella and extending distally in a reflexed manner in the same plane as $th1^1$. This theca is not attached dorsally to the ventral wall of $th1^1$. This specimen was unfortunately damaged during handling and the extra theca was broken off from the rest of the specimen before it could be photographed. One specimen from Sample 80E10-3 exhibits an extra theca projecting laterally from the left wall of $th1^1$. This theca is essentially straight (Pl.3, fig.2). One specimen from Sample 80E9-6 shows an extra theca budding from the base of the virgella and attached dorsally to the ventral surface of $th1^1$ (Pl.2, fig.8). In all three of these cases, normal astogenetic development resumes following the formation of these abnormal thecae.

3) $th1^1$ not attached dorsally to the sicula. One specimen from Sample 79E2-f show this abnormality (Pl.3, fig.1).

4) Two nemata. Three specimens exhibit this unusual feature.

In one specimen from Sample 79E2-f the bifurcation can be closely examined since the rhabdosome is only developed to $th2^1$ (Pl.3, figs. 3-5). At the bifurcation of the nema a thin web of material is located between the resulting nemata. Study with the Scanning Electron Microscope reveals that this web was secreted around the nemata as well as between them. In the other two specimens with this condition, the rhabdosome is developed distally covering the point at which the nemata originate. Bleaching of one of these specimens reveals that the bases of the interthecal septa are fused to the nema nearer to them. The base of one of these nemata is broken away and missing. Thus, it is not clear exactly where the bifurcation takes place in this specimen but it seems to be near the apex of the prosicula as in the other example. Kozlowski (1971) figures a specimen of Didymograptus sp. with a forked nema. This specimen may also have the web of material between the resulting nemata but he offers no explanation of this phenomenon in the text.

5) Delayed development of a theca. One specimen of C. pygmaeus shows an abnormal delay in the development of $th2^1$. In this specimen $th2^1$ does not cross the reverse side of the sicula until the level of $th1^2$ (Pl.2, figs. 5 and 6). This leaves an apparent gap in this rhabdosome, equal to the size of an average theca. Normal astogeny resumes following this unusual feature.

6) Bifurcation of proximal spines. Several specimens show

this developement. Either the virgella or the anti-virgellar spines may be found to bifurcate in some specimens (Pl.2, fig.7).

Genus Orthograptus Lapworth, 1873

Orthograptus sp.

Description.---Small narrow Orthograptus with a maximum width of less than 1.0 mm. Only one proximal end spine which is a short stout virgella. Thecae with straight ventral wall, inclined at 25 or less. Thecae number 13-14 in 10 mm overlapping 1/2 to 1/3 their length. Median septum absent. Isolated specimens show prominent growth rings. Sacula visible only to level of the th¹ aperture in the obverse aspect.

Discussion.---Representatives of this species were found in two samples from the upper Kope Formation at Maysville, Ky., Localities B and C. In Sample 80E5-f, this species was found sparingly along with hundreds of specimens of Climacograptus. In Sample 80E10-8, it is the dominating graptolite and occurs with a few specimens of Climacograptus. However, graptolites as a whole are scarce in this sample.

The single proximal spine makes this an unusual and easily recognizable species in the collections studied. The proximal end developement is almost identical with that of Glyptograptus euglyphus (Lapworth) as described by Finney (1977). This may indicate that this is a Late Ordovician representative of the G. euglyphus lineage. Most of the specimens of Orthograptus sp.

isolated in this study are proximal ends which are not very complete distally. No astogenetic variation in thecal form has been noted in my collections of this species.

Enigmatica

Chitinodendron bacciferum Eisenack

Chitinodendron bacciferum Eisenack, 1937, p. 236, text-figs.

9-17, Pl. 16, fig. 6; Kozlowski, 1959, p. 253-254, fig. 25.

Description.---This species consists of thin (approximately 0.02 mm wide) stipes attached to organic-walled bubble-like vesicles. The vesicles range from 0.07 mm to 0.23 mm in diameter. The walls of the vesicles are translucent brown or amber-colored. The vesicles may occupy a terminal position on a stipe or they may have stipes protruding from multiple locations on the surface. The stipes are never continuous through a vesicle, always terminating at the intersection with that vesicle. The stipes are hollow tubes, with structures resembling apertures present in some places (Pl. 4, fig. 9). The interiors of both the stipes and the vesicles frequently contain small crystals and framboids of pyrite and other minerals. Many of the small framboids are regularly rounded with almost no angular appearance at all. These small spheres were analysed with a SEM Ortec 1600 Analyser. The curve generated by this instrument was similar, but not identical, to the typical pyrite curve generated by analysis of a small pyrite cube from the same interior. These small spheres

(approximately 0.002mm average diameter) may be pyrite or they may have some other mineral content. Small pyrite spheres and framboids have been reported by Kobluk and Risk (1977) from the interiors of algal borings in brachiopod shells from the Upper Ordovician Richmond Formation of Ohio.

Discussion.---This microfossil proved to be fairly common in the samples dissolved in acid. It is, in most cases, represented by isolated vesicles with little or no attached stipe. This is undoubtedly due to the very thin and delicate nature of the stipes. The apparent abundant occurrence of this species in the Cincinnati strata is somewhat surprising since this seems to be the first find of this fossil in North America. It may well be that the care exercised in the preparation of the acid residues was a critical factor in the recovery of these delicate specimens.

The biological affinities of Chitinodendron are very difficult to determine. Eisenack (1937) placed Chitinodendron, with reservations, among the Foramenifera. Kozlowski (1959) placed it with the Hydroids. Another possibility is that Chitinodendron may be an organic-walled fungi. Johnson and Anderson (1962) reported on the occurrence of organic-walled fungi in the shells of recent Anomia simplex. Their specimens and those of Chitinodendron superficially resemble each other.

CONCLUSIONS

Climacograptus pygmaeus occurs within a very limited range in the Maysville, Kentucky area. At Maysville, it occurs in strata which have been correlated with the lower Fairview Formation of the type Cincinnati. It therefore occurs in rocks of Early Maysvillian age. If the boundary between Berry's graptolite Chronozones 13 and 14 in the Upper Ordovician of the Ohio Valley may be taken as the lowest position of *C. pygmaeus*, ^tThen this study has shown that that boundary must lie in Early Maysvillian strata. It seems likely that as more local occurrences of *C. pygmaeus* become known, knowledge of its range may shed additional light on certain lithofacies relationships between the formations of the Upper Ordovician in this region. Certainly, its occurrence in the Lexington Ky. area should be more fully investigated. It is important to realize that individual rhabdosomes may be misleading, and in order to obtain the full biostratigraphical value from a sample, large populations should be examined whenever possible.

The surprising abundance of a fossil such as *Chitinodendron* serves to illustrate the potential for further unusual microfossil occurrences even in well-known strata such as the Upper Ordovician of the Cincinnati region. Careful study of these strata will undoubtedly reveal more unusual microfossils.

ACKNOWLEDGMENTS

I would like to thank Dr. Stig M. Bergstrom for his advice and patience; Charles E. Mitchell for sending the specimens from Harvard; Dr. Lois Campbell for her help in finding the University of Kentucky specimens; The Friends of Orton Hall Fund for economic aid; Maureen Lorenz for help with the Scanning Electron Microscope; Keith Knabe for discussion of his samples; Dr. Stanley C. Finney for his advice and interest; and my wife Margo, whose moral support and love have been of inestimable value throughout this project.

Table 1

Sample 79E2-f

Thecal #	Mean Width	Variation	St. Dev.	# of Specimens
1 ¹	0.44 mm	0.39-0.52 mm	0.03 mm	99
2 ¹	0.46 mm	0.36-0.61 mm	0.05 mm	101
3 ¹	0.53 mm	0.42-0.67 mm	0.05 mm	99
4 ¹	0.59 mm	0.49-0.74 mm	0.05 mm	97
5 ¹	0.62 mm	0.50-0.82 mm	0.06 mm	103
6 ¹	0.66 mm	0.51-0.92 mm	0.08 mm	67
7 ¹	0.67 mm	0.56-0.83 mm	0.07 mm	33
8 ¹	0.72 mm	0.57-0.85 mm	0.07 mm	11
9 ¹	0.74 mm	0.71-0.78 mm	0.03 mm	7

Sample 80E10-3

1 ¹	0.44 mm	0.39-0.50 mm	0.03 mm	55
2 ¹	0.52 mm	0.47-0.63 mm	0.04 mm	55
3 ¹	0.59 mm	0.49-0.76 mm	0.05 mm	55
4 ¹	0.66 mm	0.54-0.80 mm	0.06 mm	55
5 ¹	0.72 mm	0.55-0.92 mm	0.08 mm	55
6 ¹	0.76 mm	0.58-0.95 mm	0.08 mm	36
7 ¹	0.80 mm	0.58-0.97 mm	0.09 mm	24
8 ¹	0.85 mm	0.74-1.01 mm	0.08 mm	13
9 ¹	0.82 mm	0.78-0.86 mm	0.03 mm	5

Table 2

Sample 80E3-2

Thecal #	Mean Width	Variation	St. Dev.	# of Specimens
1 ¹	0.52 mm	0.43-0.64 mm	0.04 mm	50
2 ¹	0.50 mm	0.41-0.66 mm	0.04 mm	50
3 ¹	0.53 mm	0.50-0.69 mm	0.04 mm	50
4 ¹	0.67 mm	0.60-0.78 mm	0.04 mm	49
5 ¹	0.78 mm	0.69-0.93 mm	0.05 mm	50
6 ¹	0.87 mm	0.76-1.04 mm	0.07 mm	35
7 ¹	0.94 mm	0.81-1.15 mm	0.08 mm	17
8 ¹	1.02 mm	0.84-1.23 mm	0.10 mm	12
9 ¹	1.05 mm	0.86-1.19 mm	0.10 mm	8

Sample 80E5-f

1 ¹	0.46 mm	0.40-0.52 mm	0.03 mm	49
2 ¹	0.45 mm	0.39-0.52 mm	0.03 mm	47
3 ¹	0.51 mm	0.44-0.63 mm	0.04 mm	50
4 ¹	0.59 mm	0.47-0.72 mm	0.05 mm	50
5 ¹	0.67 mm	0.55-0.82 mm	0.07 mm	50
6 ¹	0.76 mm	0.63-0.92 mm	0.08 mm	43
7 ¹	0.82 mm	0.64-1.02 mm	0.09 mm	24
8 ¹	0.89 mm	0.75-1.19 mm	0.12 mm	13
9 ¹	0.98 mm	0.79-1.28 mm	0.16 mm	7

Figure 7

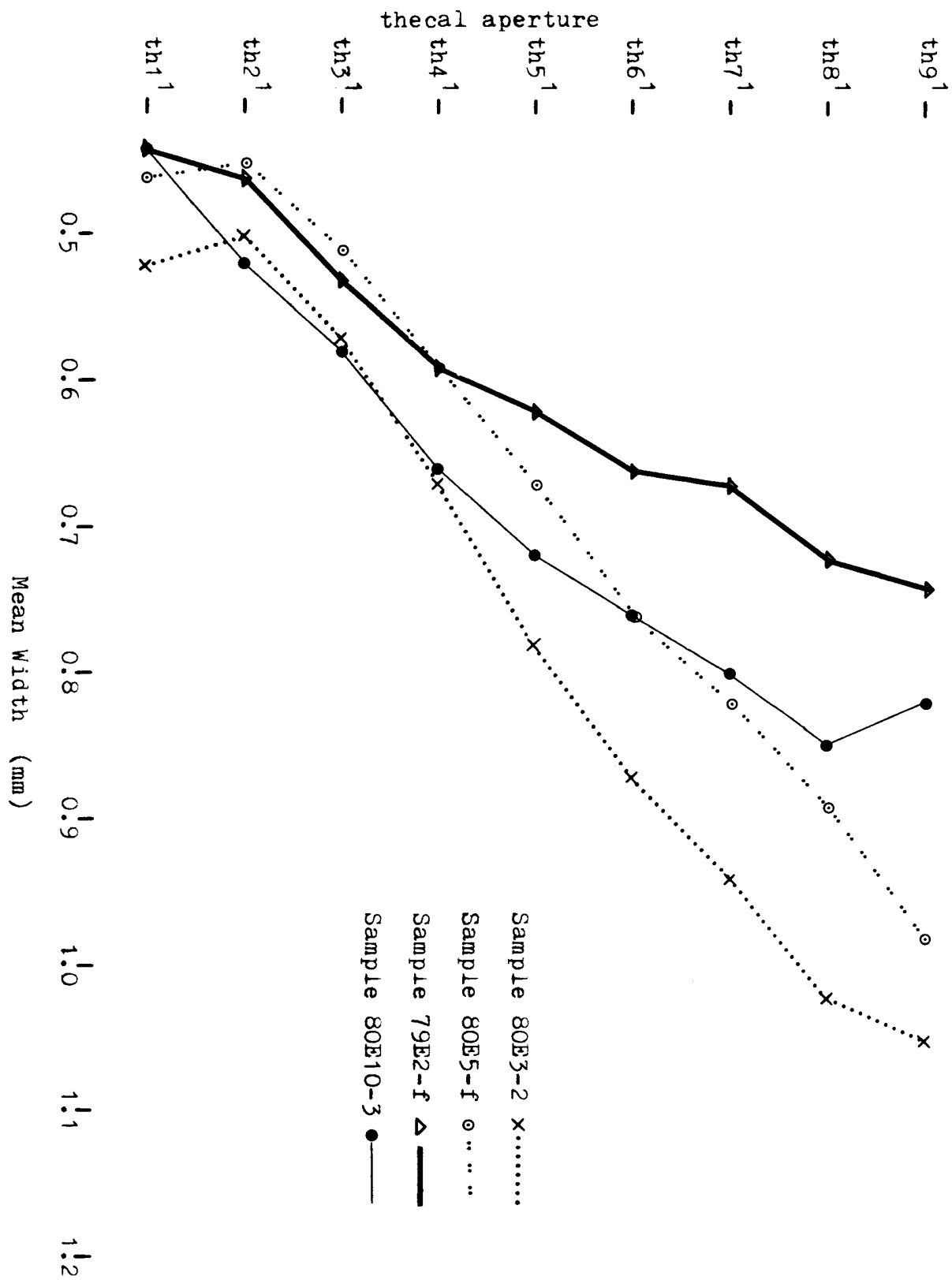


Figure 8

Sample 80E3-2
size frequency distribution

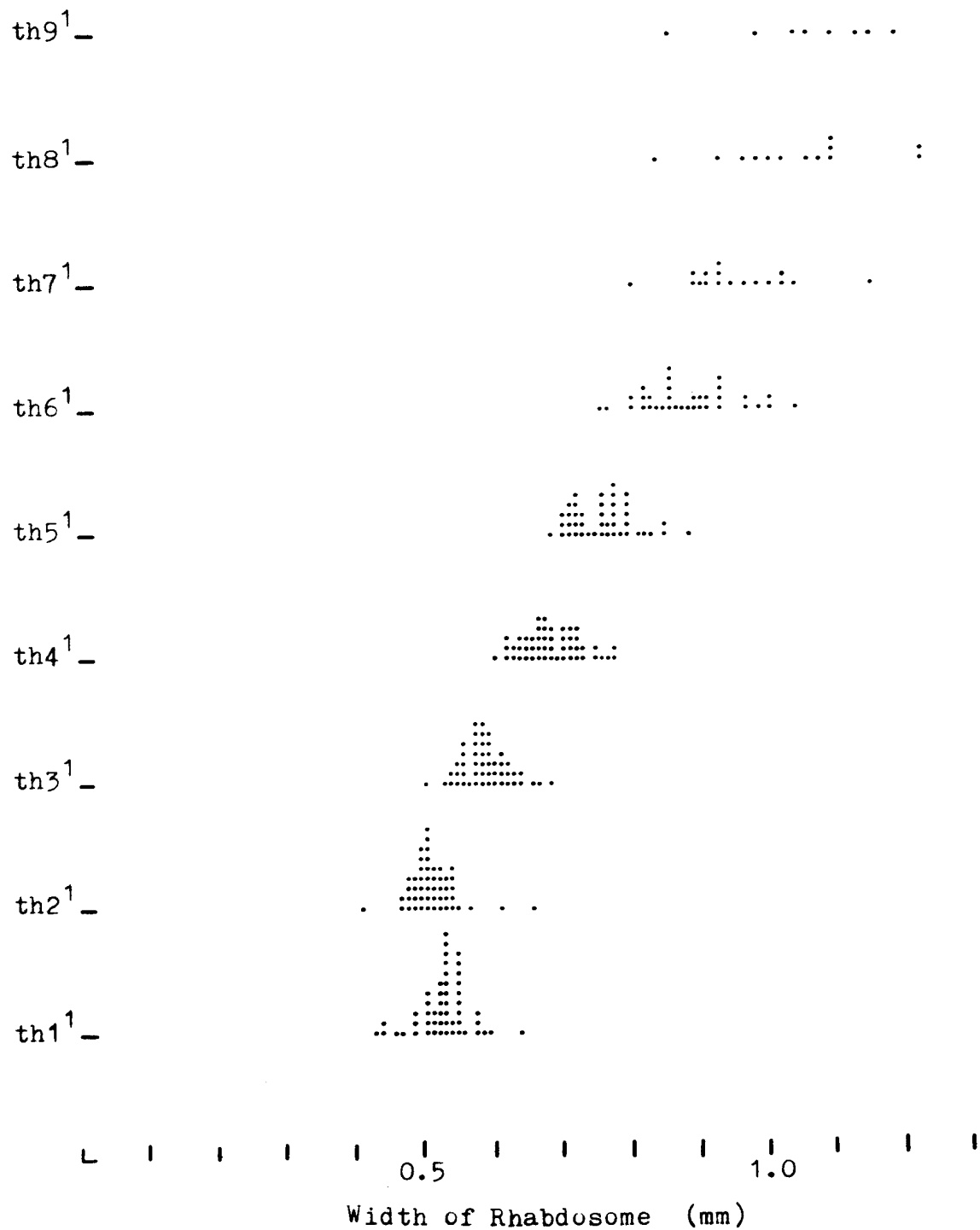


Figure 9

Sample 80E5-f
size frequency distribution

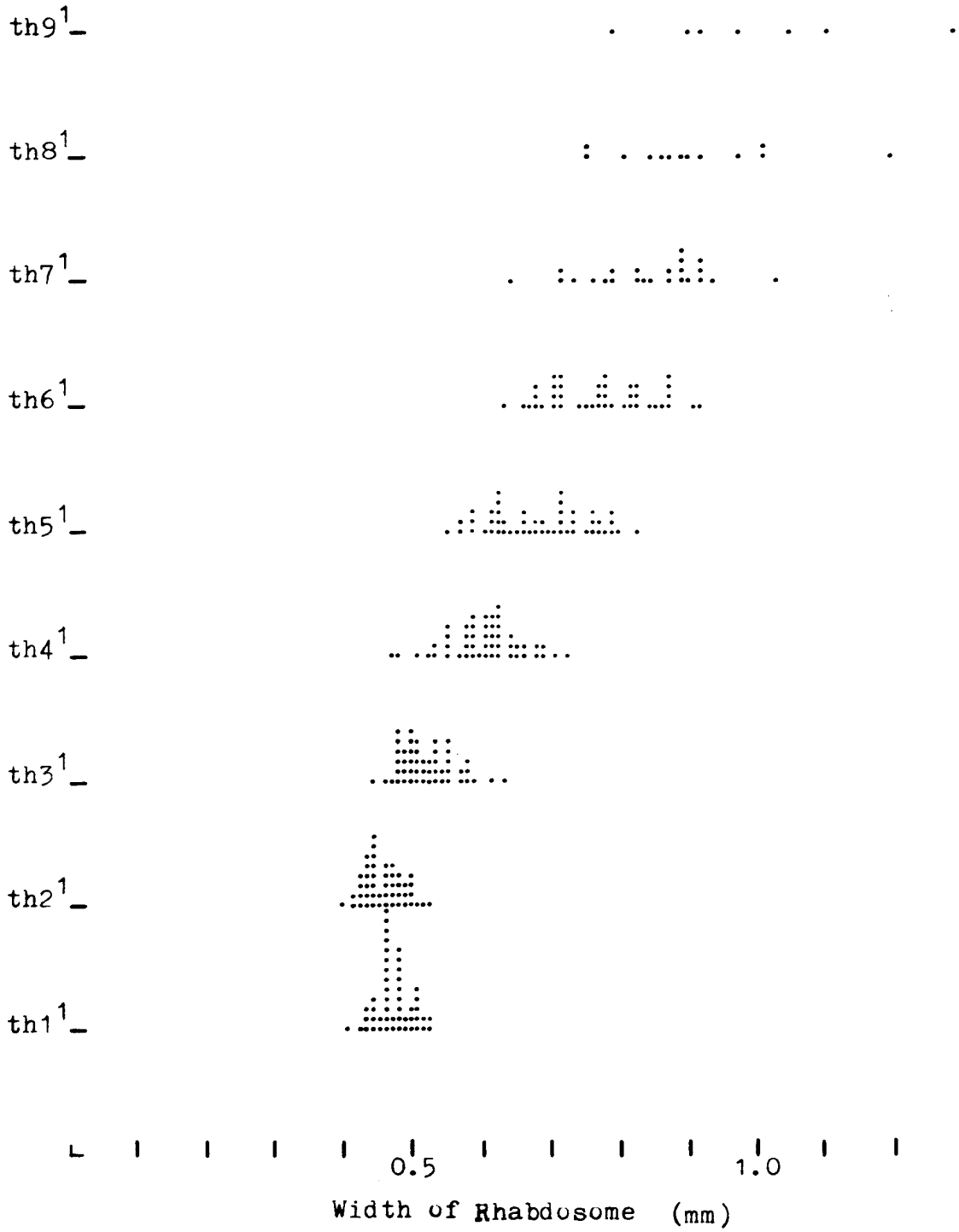


Figure 10

Sample 79E2-f
size frequency distribution

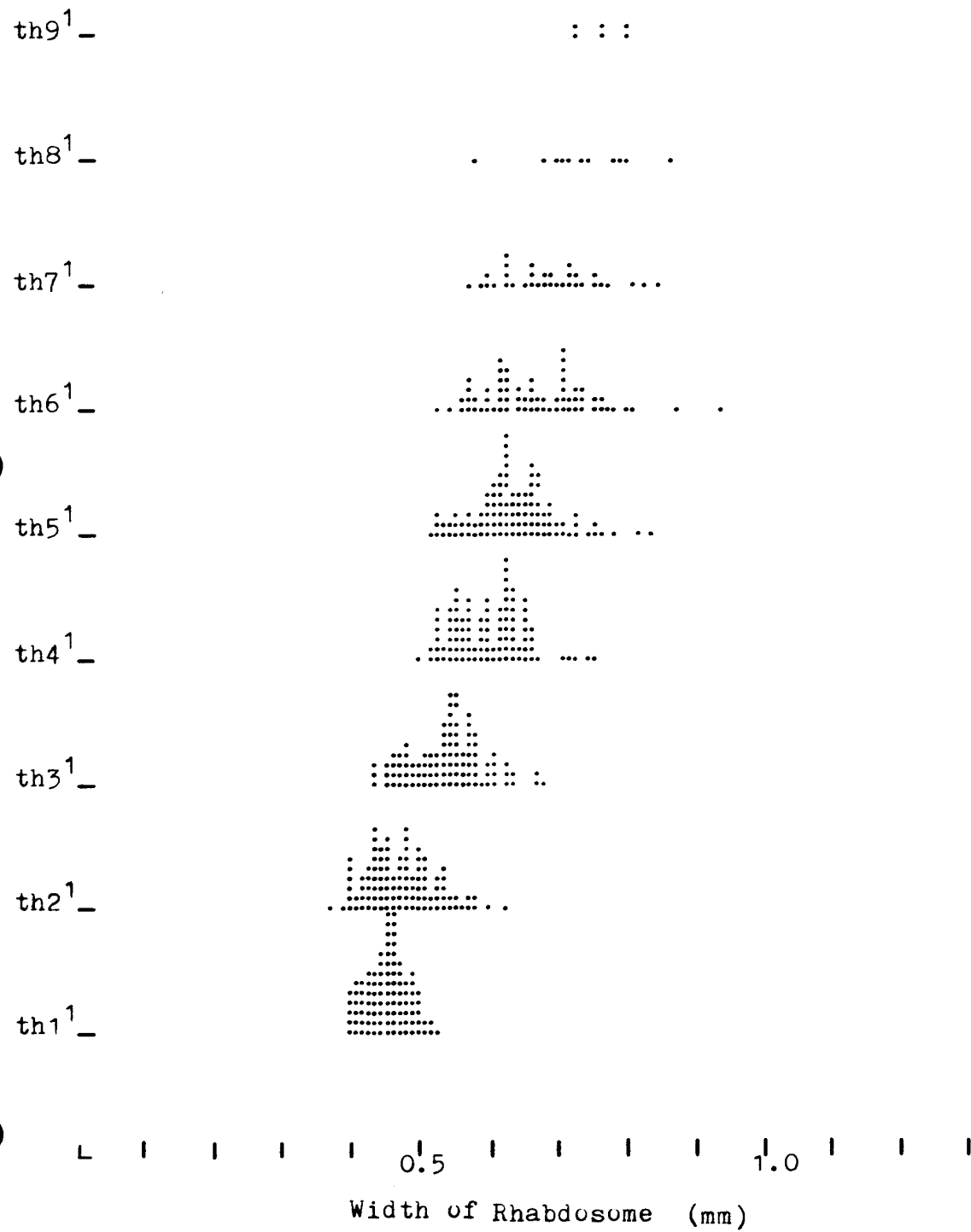


Figure 11

Sample 80E10-3
size frequency distribution

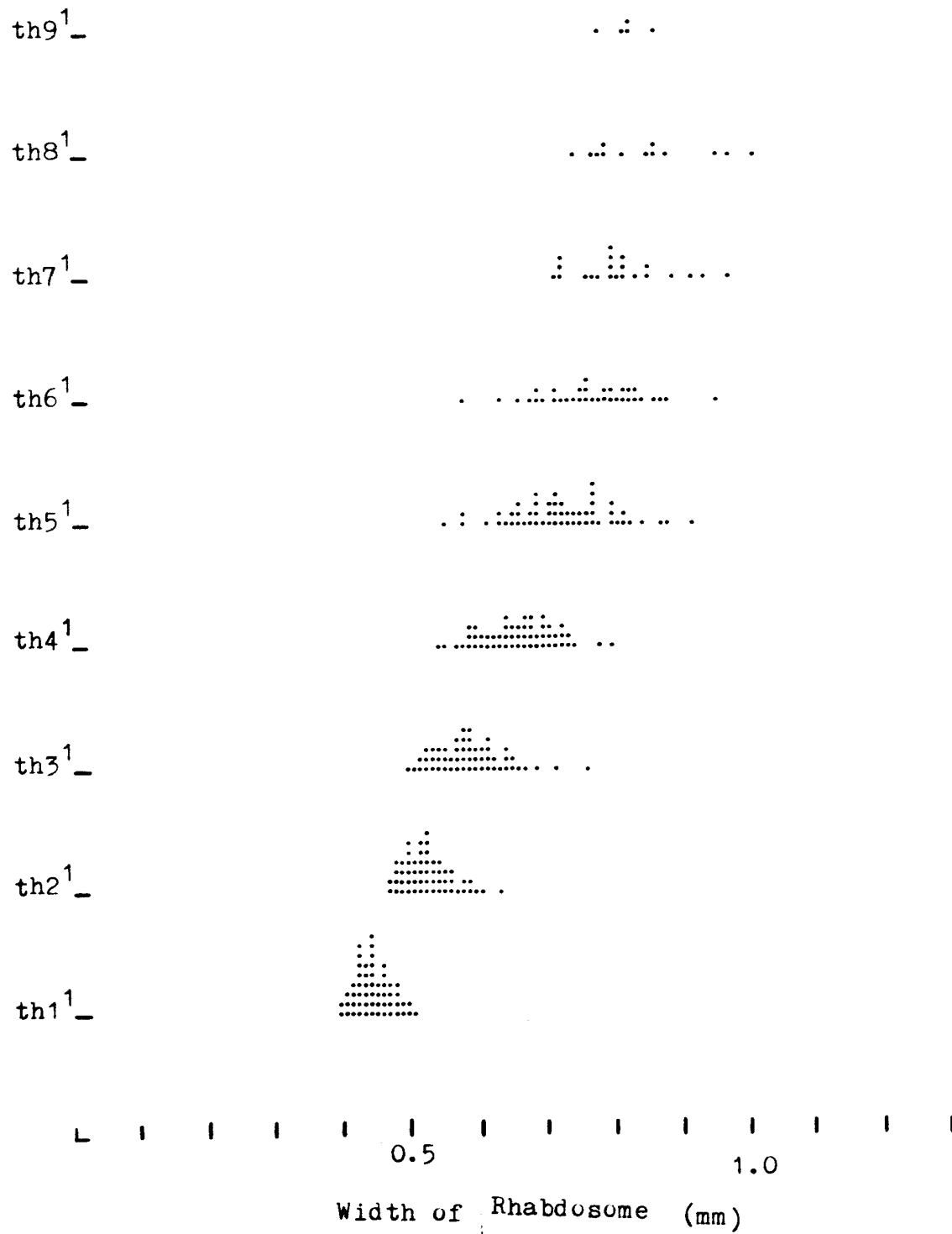
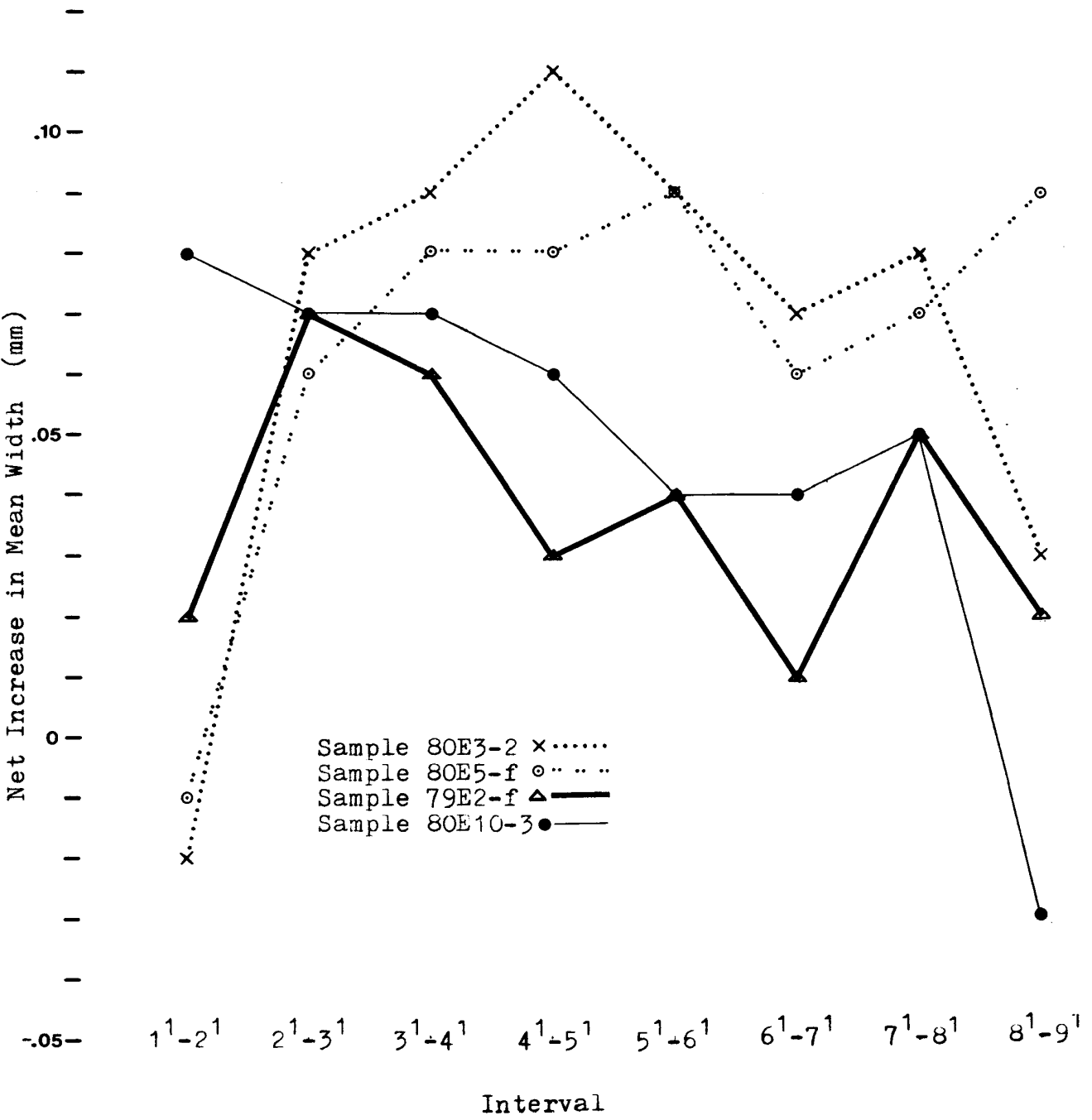


Figure 12



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PLATES

PLATE 1

Figs. 1-4. Specimens of Climacograptus pygmaeus Ruedemann
from Sample 79E2-f. 15X.

Figs. 5-6. Specimens of C. pygmaeus from Sample 80E10-3. 15X.

Figs. 7-9. Specimens of C. typicalis from Sample 80E3-2. 15X.

Figs. 10-11. Specimens of C. pygmaeus from the collections of
the Museum of Comparative Zoology, Harvard University.
15X.

PLATE 1

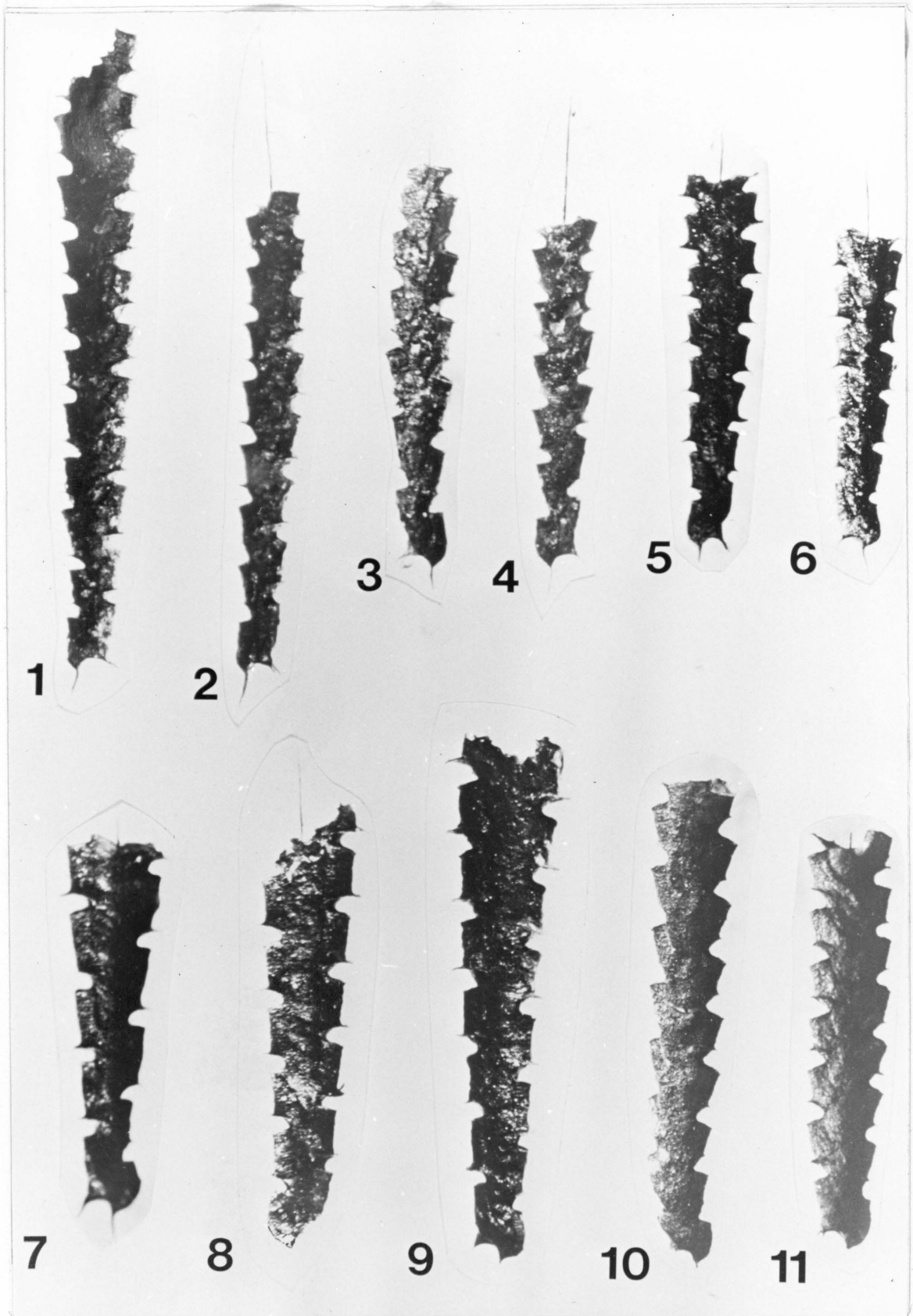


PLATE 2

Figure

- 1-4. Orthograptus sp.
1. Obverse aspect of specimen complete to th4². 15X.
 2. Obverse aspect of specimen complete to th4¹. 15X.
 3. Obverse aspect of sicula with th1¹ and partial th1². 15X.
 4. Reverse aspect of specimen showing sicula visible only to level of th1¹ aperture. 26X. SEM micrograph.
- 5-9, 11-15. Climacograptus pygmaeus Ruedemann 1925
5. Reverse aspect of specimen with delayed development of th2¹. 15X.
 6. Obverse aspect of same specimen. 15X.
 7. Specimen from Sample 79E2-f with a bifurcated anti-virgellar spine. 20X.
 8. Obverse aspect of bleached specimen with an extra theca attached to ventral surface of th1¹. 25X.
 9. Bleached specimen showing two nemata. 15X.
- 11-15. Specimens from the collections of the University of Kentucky, Department of Geology, formerly identified as Diplograptus edenensis Ruedemann. Figs. 11, 12, 14, 15. 7X. Fig. 13, 4X.
10. Climacograptus typicalis Hall 1865. Specimen showing two nemata. 15X.

All figures are reflected light photographs unless otherwise noted.

PLATE 2

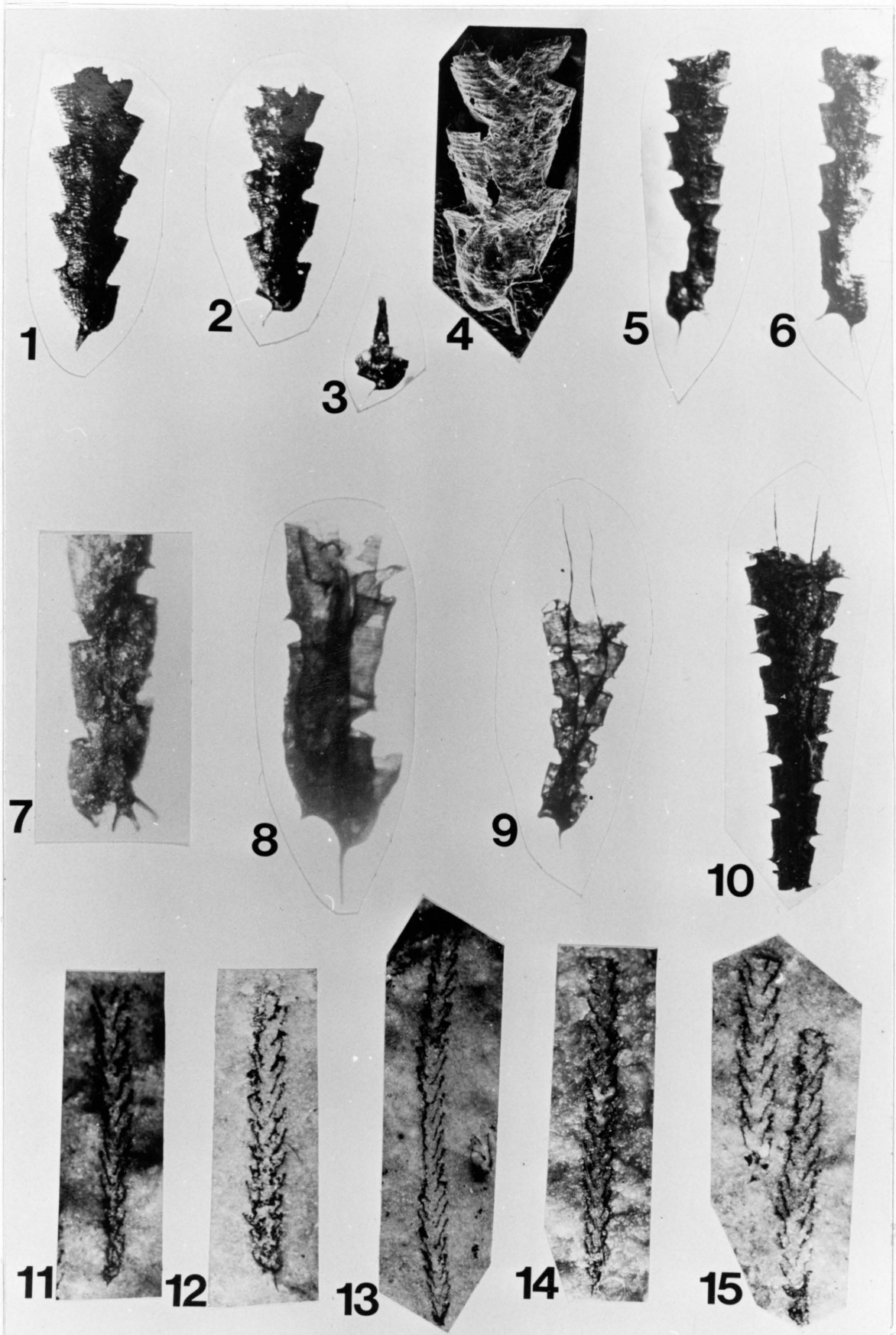


PLATE 3

Figure

- 1-5. Climacograptus pygmaeus Ruedemann 1925
1. Abnormal specimen with th1¹ not attached dorsally to the sicula. 80X.
 2. Abnormal specimen with an extra theca projecting laterally from the left wall of th1¹. 93X.
 3. Growth stage with two nemata. Specimen from Sample 79E2-f. 27X.
 4. Closer view of specimen in Fig. 3. Note two nemata projecting from the apex of the prosicula and web of material between the nemata. 260X.
 5. Closer view of web of material in Fig. 4. Note that web is secreted around the nemata as well as between them. 800X.
- 6, 7. C. typicalis Hall 1865
6. Specimen with second supragenicular flange on th6¹. From Sample 80E3-2. 15X.
 7. Closer view of specimen in Fig. 6. Note second flange on th6¹. The upper less prominent flange appears to have been secreted first by the zooid in th5¹. The lower more prominent flange was probably formed later. Also note the striking cortical bandaging visible on this specimen. 70X.

All figures are Scanning Electron Micrographs.

PLATE 3

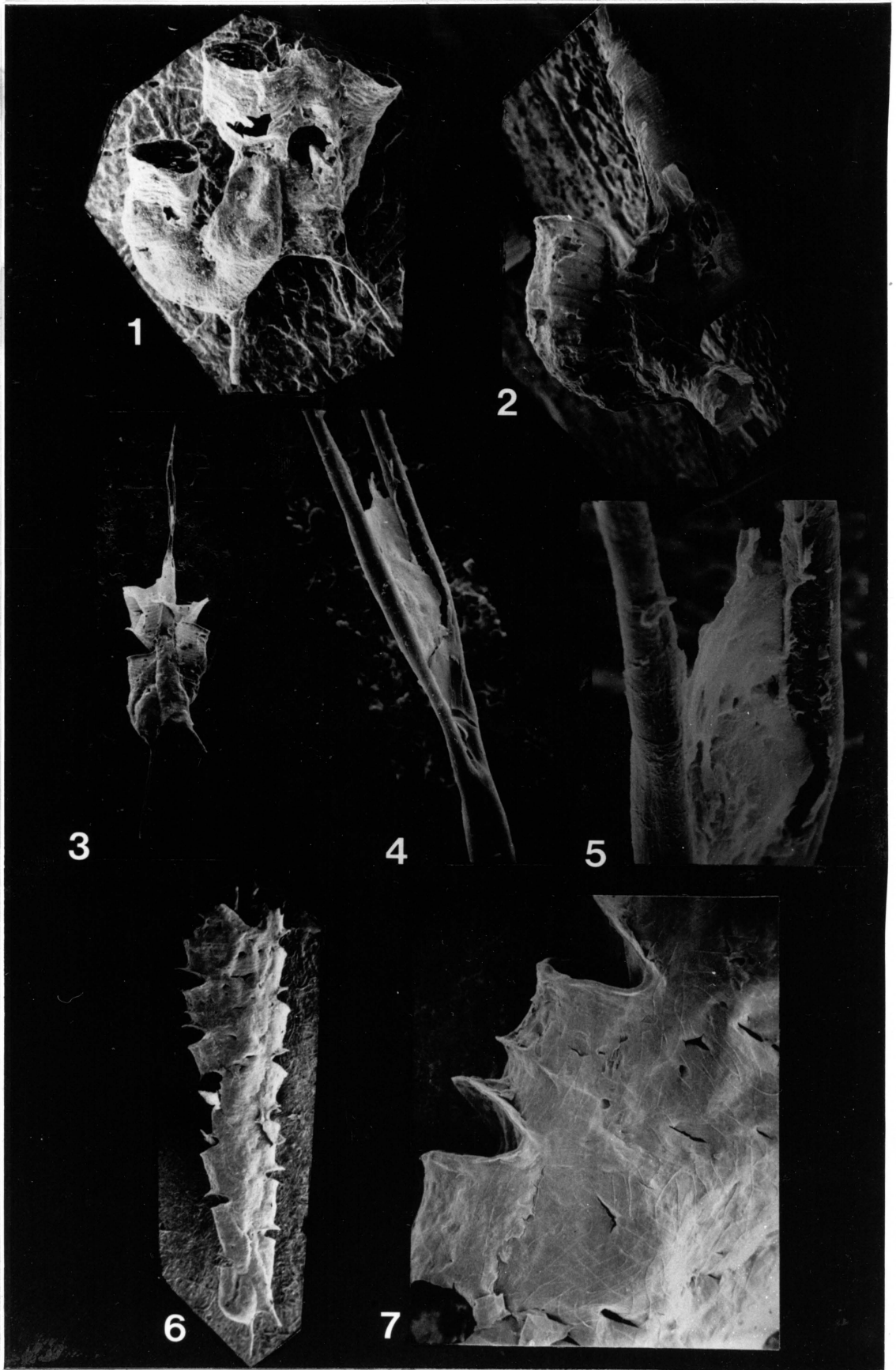


PLATE 4

Chitinodendron bacciferum Eisenack 1937

Figure

1. Specimen with bubble-like vesicle attached to branching stipe. Transmitted light photograph. 250X.
2. Closer view of branching stipe in Fig. 1. Note hollow stipes partially filled with crystals and spheres of pyrite and other minerals. Transmitted light photograph. 750X.
3. Vesicle attached to branching stipe. 200X.
4. 5 specimens in water showing a range of size and shape. Reflected light photograph. 25X.
5. Vesicle attached to stipe. Note crystal growths on this specimen. 287X.
6. Cluster of mineral spheroids at the intersection of the stipe and vesicle in Figure 5. 4330X.
7. Mineral spheres at the intersection of a vesicle and stipe. View looking into the stipe. 3470X.
8. Vesicle containing individual and clustered mineral spheres. Also note hole in exterior surface where stipe was broken off. 300X
9. "Aperture" or "pore" in stipe in Fig. 5. 4870X.
10. Mineral spheres against the wall of the vesicle. 3470X.
11. Vesicle containing individual and clustered mineral spheres. 530X.
12. Closer view of cluster of mineral spheres from Fig. 11. Note the well-rounded character. 2530X.

PLATE 4

